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Genetic Gains Through Testing and Crossing Longleaf Pine Plus Trees

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SUMMARY

A progeny test of 226 superior tree selections from nine geographic sources across the South confirmed earlier results that showed the Gulf Coast source superior in survival and growth. Family variation within a region was large and provided additional genetic gain. Control-pollinated tests of elite x elite trees yielded even more gains. Progeny of the elite x elite crosses had higher survival, less brown-spot infection, and greater wood volume than progeny from crosses involving only one or no elite parent.

Additional keywords: *Pinus palustris,* geographic variation, progeny test, survival, growth, brown-spot needle blight.

IMPROVING BREEDING PROCEDURES

Good form, natural pruning, and high quality wood favor longleaf pine (*Pinus palustris* Mill.) for use as poles and lumber in the South. Yet because of low planting survival, susceptibility to brown-spot needle blight [*Scirrhia acicola* (Dearn.) Siggers], and slow early growth, it has not been widely planted. Tree improvement offers an opportunity for overcoming these negative traits. In studies reported here, objectives were to show geographic seed source trends, family variation for each of nine geographic areas, and gains realized at ages 12 and 13 through control-pollination among elite parents.

METHODS AND MATERIALS

We established three randomized complete block studies. Test A was a progeny test of 226 superior tree selections divided among nine geographic sources across the South (Derr 1971). Included as a control were the wind-pollinated progeny of an elite parent, "Abe" (Derr 1963). In 1969, 1-year-old potted trees were planted in plowed furrows on a fertile, well-drained, sandy loam soil near Alexandria, Louisiana. Four replications of 10 seedlings per row-plot were planted at 6 ft x 8 ft spacing. Data collected or calculated were:

- Age 2 — Height and percentage of needle tissue killed by brown spot
- Age 5 — Height
- Age 8 — Height; diameter; percentage of surviving trees, trees with fusiform rust, trees with crooks, or trees with forks.

Percentage figures were transformed by an arc sine procedure for analyses of variance. For 8-year growth, average volume per tree and volume per plot were computed.

In test B, 18 random parents were wind-pollinated and control-pollinated by Abe. The Abe x wind family was included as a control. Potted seedlings from the 37 families were transplanted to plowed furrows in the spring of 1965. The study is located at Alexandria, Louisiana, and consists of three replications of 20-tree row-plots. Data were collected at age 2 from all families for height, survival, and percentage of brown-spot infection. At age 12, we remeasured height, diameter, and survival for the two random x Abe families that were tallest at age 2, Abe x wind, and random tree 3 x wind (an average random control). The two tallest random parents probably have above average genotypes. Mean volume per tree and volume per plot were computed.

In test C, we compared families derived by crossing Abe with two elite trees (including reciprocals), Abe x wind, and four random trees x wind. For comparison we grouped crosses with their reciprocal crosses and also the four random x wind crosses. These and other intermediate crosses were included in earlier analyses (Derr and Melder 1970). The test was established in 1964 at Alexandria, Louisiana, with four replications of 25-tree plots. At age 3, data were collected from all families for percentage of brown-spot infection, survival, and height. Height, diameter, and survival data were collected at age 13 from the elite x elite crosses, Abe x wind, and a representative random control (4-1 x wind). Average volume per tree and volume per plot were computed.

RESULTS AND DISCUSSION

Test A—Geographic seed source effects

After 8 years, progeny from plus trees of the south Alabama source had the largest volume per tree and volume per plot among all sources (table 1). The source means were significantly different. This confirmed results from the Southwide Pine Seed Source Study, which used randomly selected trees and showed that the Gulf Coast source excelled over most of the commercial range of longleaf (Wells and Wakeley 1970). For current reforestation and tree improvement programs in Louisiana, the Gulf Coast source should be emphasized. In this experiment the south Alabama source had 58 percent survival (vs. 29 percent for the Louisiana source) and had 157 percent more volume per plot than did the Louisiana source. On the basis of volume per plot, we should not use Texas, North Carolina, or Louisiana seed in Louisiana unless we can find better clones from these sources. The downward trend of the relative height growth of northern Alabama trees between 5 and 8 years also cautions against use of this source in Louisiana.

The South Carolina source had unexpectedly good growth. Its origin is much farther north than the three other best performing sources and is over 350 miles northeast from the recommended central Gulf Coast seed collection area. Although we would be cautious in recommending trees from the South Carolina source for planting in Louisiana, the growth potential looks good. The South Carolina source deserves additional testing, particularly in areas across the northern part of the longleaf range.

Variation in brown-spot infection contributed most to 8-year volume per plot variation among seed sources. However, additional variation was accounted for by including 2-year height growth. The prediction that provided best fit for 8-year volume was the 2-year percentage of foliage free of infection x the 2-year height growth ($R^2 = 0.91$). The high correlation is further evidence of the efficiency of early testing and selection before seed orchard establishment.

Although 2-year height growth differences were significant, the range was narrow (0.36 to 0.49 ft) and not well correlated with later height data. By age 5, family height growth differences were well expressed and correlated with 8-year

Table 1.—*Progeny performance by source of seed in test of 226 National Forest clones (Test A)*

Source	No. of Fam.	2-year Brown Spot	2-year Height	5-year Height	8-year Survival	8-year Rust	8-year Height	8-year Diameter	8-year Avg. volume/ tree	8-year Avg. volume/ plot	8-year Range volume/ plot
		Percent	*Feet*	*Feet*	*Percent*	*Percent*	*Feet*	*Inches*	*Feet³*	*Feet³*	
South Alabama	22	18	0.42	6.67	58	9	19.9	2.86	0.415	2.52	.71 — 4.39
South Carolina	37	21	0.44	6.31	56	5	19.2	2.87	0.402	2.29	.58 — 4.48
Mississippi	22	25	0.45	6.01	56	6	19.0	2.71	0.371	2.11	.65 — 3.64
Florida	25	20	0.46	6.66	49	8	20.0	2.89	0.415	2.05	.74 — 4.11
North Alabama	33	21	0.41	5.93	57	9	18.2	2.74	0.349	2.02	.73 — 3.66
Texas	42	32	0.49	5.15	39	5	18.8	2.75	0.374	1.51	.09 — 3.45
North Carolina	13	33	0.36	4.07	32	6	17.4	2.70	0.334	1.14	.52 — 2.00
Louisiana	32	38	0.40	3.73	29	6	18.0	2.60	0.320	0.98	.18 — 2.09
Mean		26	0.43	5.60	47	6	18.9	2.77	0.376	1.83	
Significance[1]		S	S	S	S	NS	S	S	S	S	

[1]S — significant at 0.01 level; NS = not significant

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heights (r = 0.?7). Height trends from age 5 to age 8 must be evaluated in conjunction with survival differences. At first, the fastest growing sources tend to survive best. As crowding begins, trees in the slower growing and less dense sources begin to catch up because they have more growing room. In this test, crowding was occurring so the study was ended.

Crook and forking is not usually a problem in longleaf pine. Mean frequency of trees crooked or forked ranged from 0 to 4 percent. Because the frequency of crook within and among sources was so low, no statistical analyses were made.

Variation and selection of families within sources

Because growth of the best families within sources is often of more interest to breeders than that of source averages for all families, we looked at the heights for the top 12 percent of the families in each source. Surprisingly, mean heights for the top 12 percent of the families from the south Alabama, South Carolina, Mississippi, Florida, and Texas sources all converged at 21.1 ± 0.1 ft. The trees are closely spaced (6 x 8 ft), and height convergence is probably caused by crowding. Under these spacing conditions, geographic source height differences are not easily differentiated by using only the tallest families.

Volume of wood per unit area is probably the most useful family selection trait. Among families with the highest wood volume per unit area, those with the highest fusiform rust or crook ratings should be avoided. In this progeny test, which is being converted to a breeding arboretum, the 70 best families out of 226 were saved. At age 8, the 70 selected families averaged 2.92 ft^3 in volume per plot, or 60 percent more than the 1.83 ft^3 average for all families. Within each 10-tree plot of each selected family, only the best tree was saved. This within-family selection will provide additional gains.

Although volume selection at age 8 may seem early enough in the life of the plantation for some, we believe that even earlier selection has some merit. We were reasonably successful in estimating 8-year volume from 2-year height and 2-year brown-spot infection. Correlation between observed and estimated values was r = 0.69. This is considered good, since we are going from a few inches tall at age 2 to 20-30 feet at age 8. Certainly by age 3 or 4, when the trees are out of the grass stage, the correlation would be even higher. Initial screening or selection at this age seems appropriate for making initial parent tree selections or for roguing a seedling seed orchard.

The 70 families were selected without regard for geographic seed source effects. The number of families selected per geographic source therefore depended upon average source performance and total number of families per source in the test. The number and percentage of families selected from each source were: SC-17 (40 percent), MS-15 (41 percent), S. AL-12 (54 percent), N. AL-10 (30 percent), FL-8 (32 percent), TX-7 (17 percent), LA-1 (3 percent), NC-0 (0 percent).[1]

This progeny test has provided satisfactory brown-spot evaluation for all families. In using these data from a single planting we assume little genotype x environment interaction for brown spot. The test will also serve for roguing on the basis of growth in the nearby Kisatchie clonal seed orchard. However, only clones from the Kisatchie Forest and Texas are included in the orchard, and their overall performance in the progeny test was poor. For greater genetic gain for this region, faster growing eastern clones should be included in the Kisatchie seed orchard.

The test information is also satisfactory for moderately roguing clones to be planted in other areas where brown spot is serious. However, for seed orchards in areas that are unlike the test region, especially North Carolina and north Alabama, this progeny test should not be used. Trees selected for adaptation to one area are not necessarily those adapted to another (Snyder and Bey 1978). In the future, orchards should include selections from the most promising geographic sources in addition to the local source. Orchards should be rogued on the basis of progeny tests in the area where the seed is to be used. Progeny testing for brown-spot resistance and early growth is necessary for rapid advancement in tree improvement programs.

Tests B and C—Crossing among the elite

Material similar to the elite clones in Test A were intercrossed (table 3). Results at age 12 to 13 indicate that much additional gain can be made by intercrossing elite parents. Progeny of crosses involving elite parents generally survived much better than progeny from crosses involving only one or no elite parent. The poor survival of wind-pollinated (random) material is perhaps the most surprising and important result of all. Only progeny from the elite x elite

[1] Data similar to those for south Alabama for all 226 families for brown spot, fusiform rust, survival, 5-year height, and 8-year volume (table 2) are available from the authors.

Table 2.—*The ranks of families from the Conecuh N.F., Alabama (Test A) ranked by volume per plot*

Forest and clone ID	2-year brown spot	5-year height	8-year rust	8-year survival	8-year vol/tree	8-year vol/plot
	Percent	*Feet*	*Percent*	*Percent*	*Feet³*	*Feet³*
12 AL CON 68 23	9	9.04	3	30	0.551	4.391
20 AL CON 100 31	8	8.92	3	72	0.504	3.821
22 AL CON 165 41	11	8.90	9	80	0.485	3.802
2 AL CON 18 19	18	7.17	27	60	0.542	3.511
4 AL CON 36 14	12	7.74	3	71	0.455	3.184
6 AL CON 47 8	14	7.32	15	70	0.439	2.938
17 AL CON 92 6	14	7.31	3	65	0.421	2.890
15 AL CON 75 3	22	7.24	18	63	0.449	2.772
10 AL CON 61 10	10	7.31	11	65	0.414	2.713
11 AL CON 65 12	15	7.76	4	55	0.490	2.623
3 AL CON 35 13	20	6.38	18	60	0.447	2.597
5 AL CON 40 16	20	7.46	6	65	0.395	2.566
19 AL CON 98 30	16	6.42	15	60	0.381	2.278
21 AL CON 138 18	19	6.81	15	52	0.410	2.222
18 AL CON 96 28	20	6.75	9	52	0.391	2.218
16 AL CON 80 4	16	6.25	10	62	0.347	2.189
14 AL CON 72 25	26	5.72	4	47	0.390	2.019
13 AL CON 71 24	15	4.93	3	52	0.305	1.775
7 AL CON 50 9	21	5.31	15	50	0.331	1.690
9 AL CON 58 21	26	4.41	0	40	0.351	1.450
8 AL CON 55 20	21	4.63	0	38	0.246	1.027
1 AL CON 4 2	39	2.88	13	15	0.386	0.714
Means for:						
Conecuh N.F., Ala.	18	6.67	9	58	0.415	2.518
Region	26	5.60	6	47	0.376	1.830
Control (Abe)	22	6.40	0	56	0.483	2.510

crosses had acceptable survival (35 to 86 percent). Survival in the random x wind and even Abe x wind progeny was very poor (0 to 18 percent). It is hardly surprising that planting run-of-the-mill longleaf seedlings has been discouraging to many foresters.

Families derived from crossing elite x elite parents also were taller, had better brown-spot resistance, greater volume per tree, and five or more times greater volume per plot than random material. In Test C, progeny in the best cross (1-2 x Abe) averaged about 3 feet per year in height growth and one-half inch per year in diameter growth. The general superiority in height growth at age 12 to 13 for crosses between elite parents can be attributed in part to their coming out of the grass stage earlier and in part to their brown-spot resistance. Many trees from the elite parents were out of the grass stage by age 3. In most cases, brown-spot incidence in progeny of elite parents was one-third to one-half that of random material.

The high correlation between early brown spot readings and 8-year volume in this study and evidence from other studies suggest that for first generation orchards, the use of short-term, open-pollinated progeny tests that are completed before grafting might be more efficient than the traditional pine seed orchard approach (Schoenike and Williams 1975). Rather than using rigorous individual tree selection standards, we recommend that a larger number of less intensively selected parent trees be tested. As shown in this study, even with intensive phenotypic selection, many trees with low breeding value are included. Rather than grafting parents into an orchard at time of selection, we recommend waiting until the breeding value is estimated from open-pollinated progeny tests. Then the elite can be grafted into an orchard, or the progeny test itself can be heavily rogued to make a seedling seed orchard.

If the latter approach is adopted, trees can be closely spaced to accommodate early roguing (Snyder and Derr 1972, Rockwood and Kok 1977). Whatever approach is used, tree improvement specialists need to recognize and use geographic variation to obtain maximum improvement for the species.

Table 3.—*Open- and controlled-pollination result. for random and elite parents in progeny tests B and C*

Type of Pollination	Brown Spot *percent*	Survival *percent*	Ht *inches*	Survival *percent*	Ht *feet*	D.B.H. *inches*	Vol/tree *feet*^{3}	Vol/plot *feet*^{3}
Test B	Age 2			Age 12				
Random (19Y) x Elite Abe	41	98	24	47	29	6.0	2.19	20.6
Random (9R) x Elite Abe	37	95	23	35	32	6.0	2.39	16.7
Abe x Wind	62	93	11	12	26	5.5	1.60	3.8
Random (1Y) x Wind (control)	75	87	5	0	0	0	0	0
18 random trees x Abe	52	92	16	—	—	—	—	—
18 random trees x wind	74	90	5	—	—	—	—	—
Significance[1]	S	NS	S	S	NA	NA	NA	NA
Test C	Age 3			Age 13				
Elite 1-2 x Elite Abe	19[2]	99	28[2]	86	38	6.2	3.30	71.0
Elite 1-3 x Elite Abe	22	100	25	85	34	5.7	2.36	50.0
Elite Abe x Wind	42	94	21	58	35	5.6	2.44	35.6
Random 4-1 x wind	65	99	6	18	31	5.2	2.18	10.0
4 random trees x wind	65	96	8	—	—	—	—	—
Significance[1]	S	NS	S	S	S	NS	S	S

[1]S — signficant at .05 level; NS — not-significant; NA — not applicable because there were no surviving controls
[2]Data from Derr and Melder 1970.

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